CLAIMS

What is claimed is:

1. A torque sensor comprising:

a shaft comprising magnetostrictive material;

a pair of opposite magnet poles defining an axis that is aligned tangentially to a circumferential surface of the shaft so as to induce a localized magnetic field in the magnetostrictive material between the opposite magnet poles; and

at least one torque-sensing flux detector positioned to detect a component of the localized magnetic field which escapes from the magnetostrictive material when the shaft is torqued.

2. A torque sensor according to claim 1, wherein the at least one torque-sensing flux detector comprises a pair of torque-sensing flux detectors positioned on opposite sides of the shaft circumferentially displaced from the pair of opposite magnet poles.

3. A torque sensor according to claim 1, further comprising a magnet-monitoring flux detector positioned to detect the magnetic field produced by one of the magnet poles prior to penetration into the shaft.

4. A torque sensor according to claim 1, wherein the magnet poles are permanent magnet poles.

5. A torque sensor according to claim 1, wherein the magnet poles are electro-magnet poles.

6. A torque sensor according to claim 1, wherein the shaft is hollow.

7. A torque sensor according to claim 1, wherein the shaft is made substantially only from the magnetostrictive material.

8. A torque sensor according to claim 1, wherein the shaft comprises a main body of non-magnetostrictive material and an outer layer of the magnetostrictive material.

9. A torque sensor according to claim 1, wherein the shaft comprises a main body of magnetostrictive or non-magnetostrictive material surrounded by a layer of low permeability material which is in turn surrounded by an outer layer of the magnetostrictive material.

10. A torque sensor according to claim 9, wherein the pair of opposite magnet poles are poles of a single magnet.

11. A steering column having a torque sensor comprising:

a shaft comprising magnetostrictive material;

a pair of opposite magnet poles defining an axis that is aligned tangentially to a circumferential surface of the shaft so as to induce a localized magnetic field in the magnetostrictive material between the opposite magnet poles; and

at least one torque-sensing flux detector positioned to detect a component of the localized magnetic field which escapes from the magnetostrictive material when the shaft is torqued.

12. A steering column according to claim 11, wherein the torque-sensing flux detector and the further torque-sensing flux detector are positioned on opposite sides of the shaft circumferentially displaced from the pair of opposite magnet poles.

13. A torque sensor comprising:

a shaft comprising magnetostrictive material;

a first pair of opposite magnet poles defining a first axis that is aligned tangentially to a circumferential surface of the shaft so as to induce a first localized magnetic field in the magnetostrictive material in a first circumferential direction;

a second pair of opposite magnet poles arranged axially displaced along the shaft from the first pair of opposite magnet poles and defining a second axis that is aligned tangentially to the circumferential surface of the shaft so as to induce a second localized magnetic field in the magnetostrictive material in a second circumferential direction opposed to the first circumferential direction; and

first and second torque-sensing flux detectors positioned to detect first and second components of the first and second localized magnetic fields which escape from the magnetostrictive material when the shaft is torqued.

14. A gearbox having a torque sensor comprising:

a shaft comprising magnetostrictive material;

a pair of opposite magnet poles defining an axis that is aligned tangentially to a circumferential surface of the shaft so as to induce a localized magnetic field in the magnetostrictive material between the opposite magnet poles; and

at least one torque-sensing flux detector positioned to detect a component of the localized magnetic field which escapes from the magnetostrictive material when the shaft is torqued.

15. A gearbox according to claim 14, wherein the torque-sensing flux detector and the further torque-sensing flux detector are positioned on opposite sides of the shaft circumferentially displaced from the pair of opposite magnet poles.

16. A torque sensor comprising:

a shaft comprising magnetostrictive material;

a pair of opposite magnet poles arranged on one side of the shaft and defining an axis that is aligned substantially perpendicular to a principal axis of the shaft so as to induce a localized magnetic field in the magnetostrictive material between the opposite magnet poles; and

at least one torque-sensing flux detector positioned to detect a component of the localized magnetic field which escapes from the magnetostrictive material when the shaft is torqued.

17. A method of sensing torque comprising:

(a) providing a shaft comprising magnetostrictive material;

(b) applying an external magnetic field to the shaft using a pair of opposite magnet poles defining an axis that is aligned tangentially to a circumferential surface of the shaft so as to induce a localized magnetic field in the magnetostrictive material between the opposite magnet poles;

(c) torquing the shaft so that a component of the internal magnetic field escapes from the magnetostrictive material; and

(d) detecting the escaped component of the internal magnetic field and providing a torque signal responsive thereto.

18. A method according to claim 17, wherein the detecting of the escaped component of the internal magnetic field is performed using a pair of torque-sensing flux detectors positioned on opposite sides of the shaft circumferentially displaced from the pair of opposite magnet poles.